SYNCHRONIZED MEASUREMENTS OF MAXIMUM BLOOD FLOW VELOCITIES IN CAROTID, BRACHIAL AND FEMORAL ARTERIES, AND ECG IN HUMAN POSTURE CHANGES

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Abstract-**In this research, the system has been developed to measure the maximum blood flow velocity simultaneously by an ultrasonic Doppler technique in three arteries during posture changes. As a peculiarity of this system, two semicircular transducers of 15.0mm in diameter were used as a transmitter to irradiate a wide ultrasonic beam and a receiver. Because, the position relation between an artery and transducers change rapidly during exercise. This system could be applied to a human body changing from a sitting position to an erect position with voluntary muscle constriction. As a result of measurements, the maximum blood flow velocity in femoral artery has been increased significantly in posture changes like the above.**

***Keyword*-ultrasonic Doppler method, blood flow measurement, maximum blood flow velocity, blood vessel position shift**

1. INTRODUCTION

It is expected that the dynamics of blood flows in exercising include a lot of useful information as to medical diagnoses and functional analyses of blood circular systems [1-5]. There are two kinds of non-invasive blood flow measurement technique, one is to utilize ultrasonic methods, another to use optical ones. The ultrasonic Doppler technique can measure dynamics of blood flows in the artery that exists in the deep place of the human body [1-5]. Since the position of the artery and the transducers change rapidly during exercise, conventional ultrasonic systems using narrow directional transducers are difficult to measure a dynamics of blood flows during exercise.

The purpose of this research is to measure blood flow velocities in the human artery during exercise [5]. For this purpose, wide ultrasonic beam is realized by using semicircular transducer of 15.0mm in diameter. Measurement system using an ultrasonic Doppler technique has been developed, which is able to measure the maximum blood flow velocities during posture changes.

2. MATERIALS AND METHODS

A. Systems

As shown in Figure 1, a system consists of six parts: an ultrasonic probe, a Doppler signal discriminator, an electrocardiogram (ECG) circuit, a hemodynamometer, an A/D converter and a personal computer.

A continuous wave ultrasonic signal of 2.0MHz is irradiated to the human three arteries (carotid, brachial and femoral) in the human, and the ultrasonic probe receives the signal reflected from the arteries. Frequencies of the reflected signal from artery blood flows are shifted by Doppler effect. After shifting the Doppler signal to an audio band in a frequency region, a 4-order low-pass filter of 4.2kHz and a 4-order high-pass filter of 100Hz are used to remove high frequency noise and low frequency noise due to slow moving of the blood vessels in the tissues. The Doppler signal is digitized and saved to a personal computer.

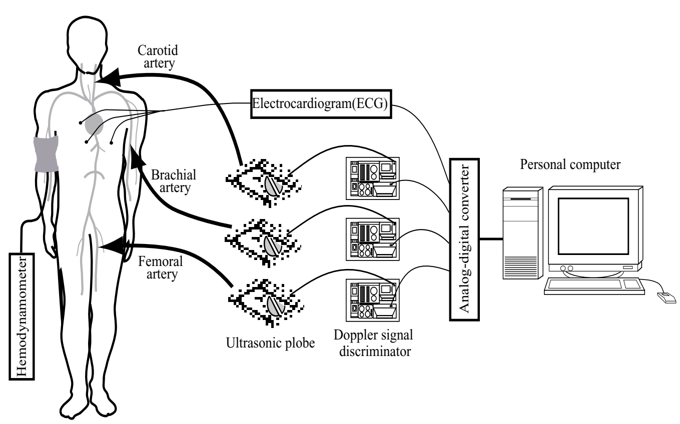

Fig.1.Constitution of a measurement system

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The Doppler signal is analyzed by 256 points (25.6ms) fast Fourier transform (FFT) with a Hanning window. FFT is repeated by using successive 256 data, which are given by shifting 128 data in turn. The relation of a blood flow velocity (Vd) and a Doppler shift frequency (fd) is given by

$$Vd = \frac{C \bullet fd}{2f_O \bullet \cos\theta}$$

where, C=1540(m/s) is the sound speed in a human body, f_0 is an irradiated ultrasound frequency and θ=45deg is the angle of the transducers and the blood vessel (Figure 2).

Pseudo-three-dimensions (3-D) graph, as a result of these analyses, and an enlarged pseudo 3-D graph are shown in Figure 3. The triangle in enlarged pseudo 3-D graph is a pulsation. We pay attention to the point of maximum blood flows velocity in pulsation.

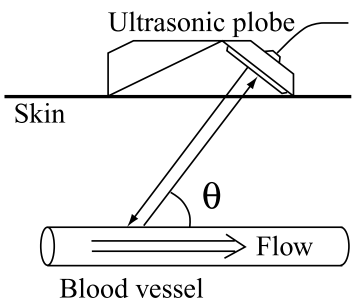

Fig.2.Angle of transducers and a blood vessel

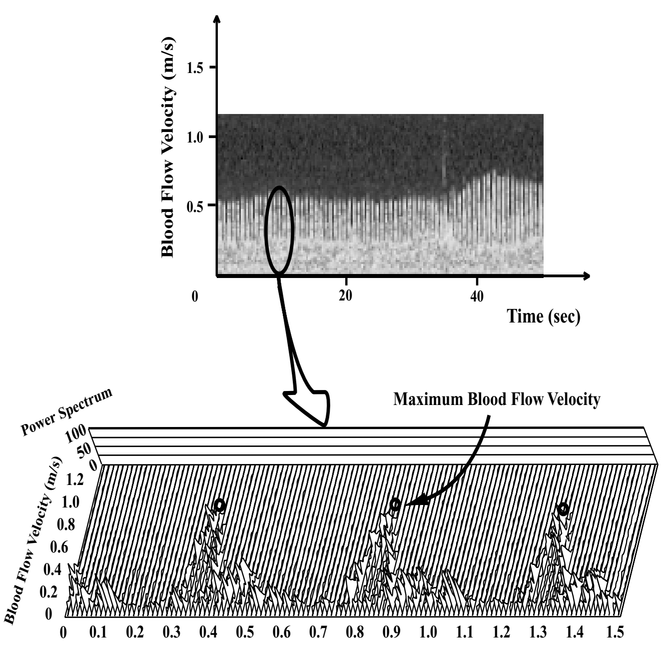

Fig.3. Pseudo-three-dimensions graph of blood flow velocity distributions

B. Problems and Solutions

There are two problems for measuring blood flow velocities by ultrasonic Doppler effects from a human body during exercise. The first problem is that the probe itself may shift on the skin. As a result, noise mixes in the Doppler signal. In this research, probes have been fitted to in the human body using an elastic belt so as not to shift during exercise (Figure 4).

The second problem is that the position relation between an artery and a probe change rapidly by exercise. As a result, blood vessels are moved out from ultrasonic irradiation field. The maximum blood vessel position shift was measured at the carotid, the brachial and the femoral arteries by using an ultrasonic diagnostic equipment. For five subjects, the vessel position was shifted to its maximum with curvature movement of a foot, an arm and a neck and so on. The carotid artery position moved 14.3mm with maximum from the erect position. Similarly, the maximum position shift was 11.9mm and 20.3mm for the brachial and femoral arteries respectively. In this research, the transmitter and receiver are changed into semicircular transducers of 15.0mm from that of 7.0mm in diameter to extend the ultrasonic irradiation range. The system can therefore work for a certain amount of blood vessel position shift.

C. Experiments

The blood flow velocity, blood pressure and ECG of five normal subjects have been measured for the carotid, brachial and femoral arteries. These are major peripheral arteries in human body. Besides, when converting a Doppler frequency into a blood flow velocity, resultant errors may be small because the arteries are parallel to the skin (Figure 5).

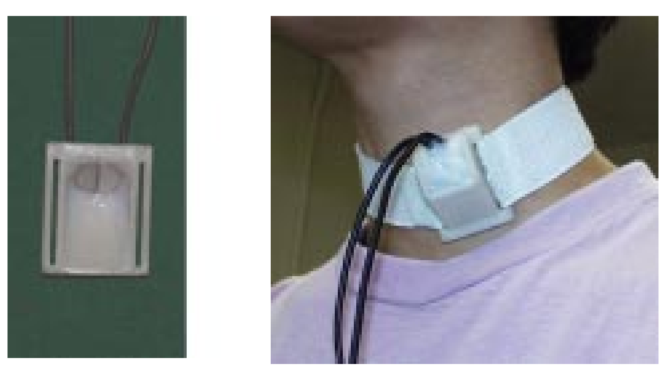

Fig.4.Photograph of the probe installation

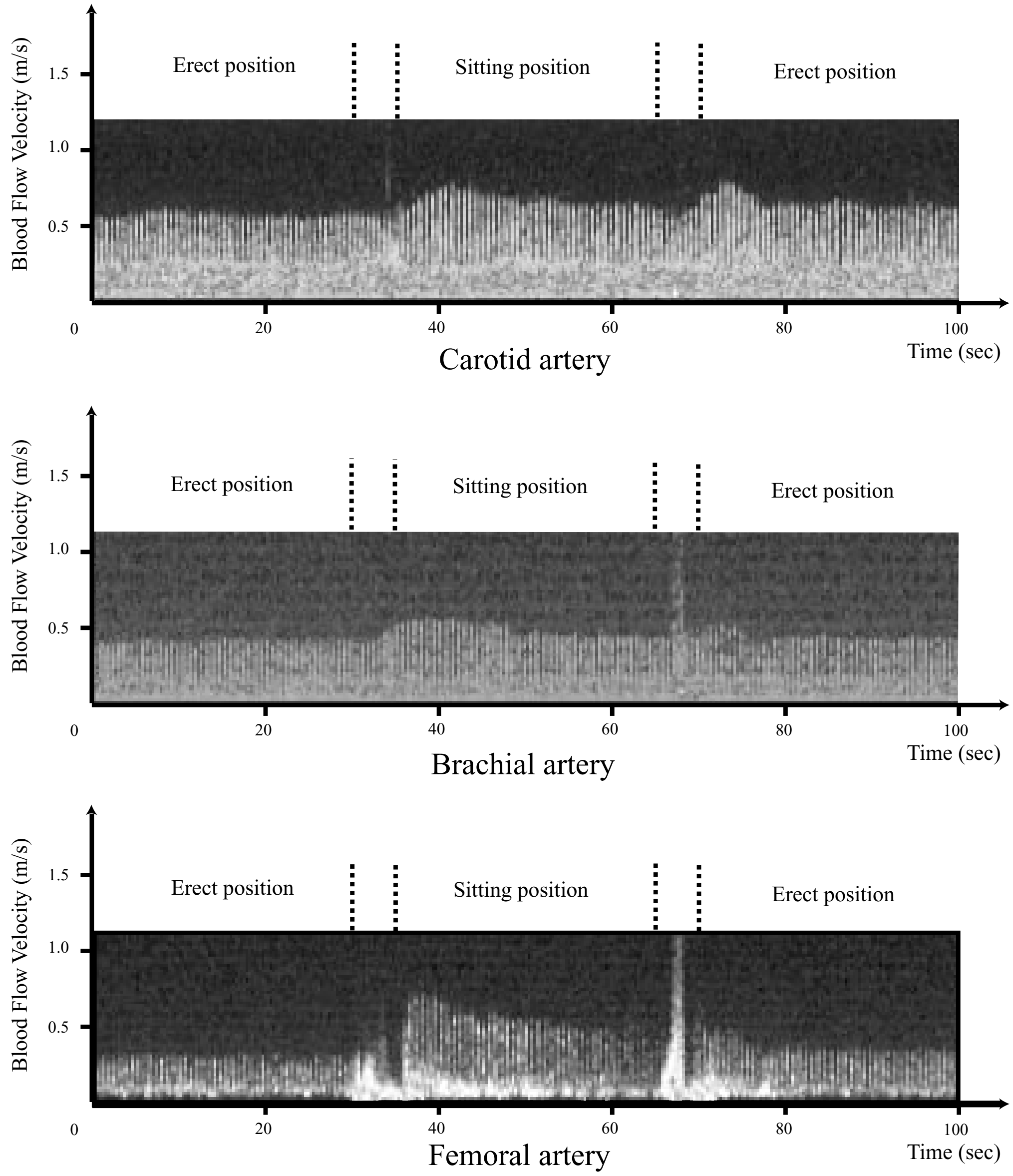

Fig.6.Pseudo-three-dimension (3-D) graph of blood flow velocity in the carotid, the brachial and the femoral arteries from a subject at thirty five ages during posture changes

Table.1.The Blood pressure and the heart rate during change from the erect position to the sitting position

	Erect position	Sitting position	Erect position
Systolic pressure	140	134	141
Diastolic pressure	112	97	98
Heart rate	86	83	79

We have measured continuously dynamics of blood flows during the posture changes. The subjects have changed the posture from the erect position to the sitting position. Each posture change is performed in five seconds, and subject has been stood still for thirty seconds with each posture. Dynamics of blood flows and ECG has been measured for a hundred seconds in total, and on the other hand the blood pressure has been measured once with each posture. As for

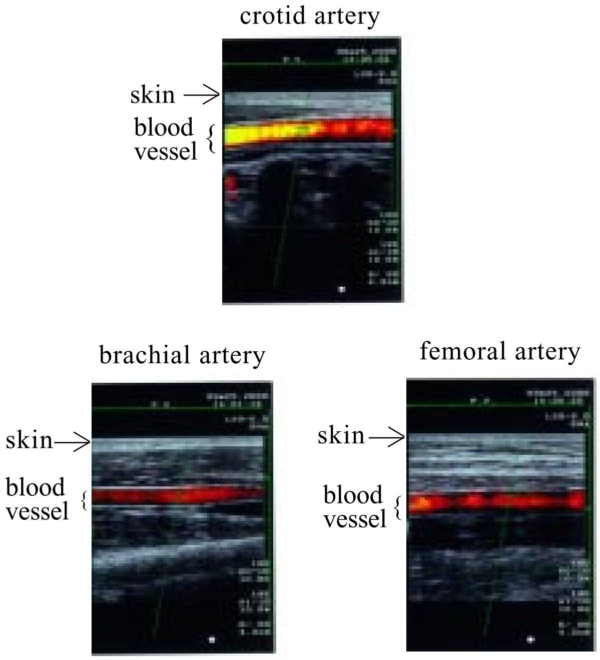

Fig.5. Position relation of a skin and a blood vessel

this experiment, the blood vessel may shift significantly with posture changes.

3. Results and Discussion

The pseudo 3-D graphs of blood flow velocities in the carotid, the brachial and the femoral arteries and blood pressure shown in Figure 6 and Table 1. The position of the blood vessel moves significantly by posture changes.

When the subject changes from the sitting position to the erect position, Doppler signal includes spontaneous velocity components in the brachial and the femoral arteries. This components is considered to be a noise that occurs with movements of the muscle during exercise because signal exists in the whole velocity component uniformly. However, the change of the maximum blood flow velocities is observed obviously in the pseudo 3-D graph.

The maximum blood flow velocity in all arteries increases with the change of postures. It increases significantly at the femoral artery because of intense contraction of the muscle around the artery.

4. Conclusion

We measured the maximum blood vessel position shift in the carotid, the brachial and the femoral arteries and changed into semicircular transducer of 7.0mm in diameter to that of 15.0mm in diameter. As a result, the blood vessel position shifted during posture changes but this system had been measured to a blood flow velocities by using an ultrasonic beam widely. The noise which, occurs with probe shift on the skin was removed because the ultrasonic probe has been fitted in the body using an elastic belt. As for experiment that subject change from the erect position to the sitting position, the change of maximum blood flow velocity was observed obviously in the pseudo 3-D graph.

The maximum blood flow velocity increases in these arteries with posture changes. In three arteries, the femoral artery shows the largest velocity change because of a strong muscle contraction.

In this way, this system is effective for the simultaneous measurements of the maximum blood flow velocities at several points during the posture changes like stand up from chair and sit down.

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